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REPORTS OF ORIGINAL INVESTIGATIONS

A deliberately restricted laryngeal view with the GlideScope® video laryngoscope is associated with faster and easier tracheal intubation when compared with a full glottic view: a randomized clinical trial

Une vue laryngée délibérément restreinte à l'aide du vidéolaryngoscope GlideScope® est associée à une intubation trachéale plus rapide et plus aisée qu'une vue glottique totale: une étude clinique randomisée

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Abstract

Introduction *During video laryngoscopy (VL) with angulated or hyper-curved blades, it is sometimes difficult to complete tracheal intubation despite a full view of the larynx. When using indirect VL, it has been suggested that it may be preferable to obtain a deliberately restricted view of the larynx to facilitate passage of the endotracheal tube. We used the GlideScope® GVL video laryngoscope (GVL) to test whether deliberately obtaining a restricted view would result in faster and easier tracheal intubation than with a full view of the larynx.*

Methods *We recruited 163 elective surgical patients and randomly allocated the participants to one of two groups: Group F, where a full view of the larynx was obtained and held during GVL-facilitated tracheal intubation, and Group R, with a restricted view of the larynx (< 50% of glottic opening visible). Study investigators experienced in indirect VL performed the intubations. The intubations were recorded and the video recordings were subsequently assessed for total time to intubation, ease of intubation using a visual analogue scale (VAS; where 0 = easy and 100 = difficult), first-attempt success rate, and oxygen saturation after intubation. Complications were also assessed.*

Results *The median [interquartile range (IQR)] time to intubation was faster in Group R than in Group F (27 [22-36] sec vs 36 [27-48] sec, respectively; median difference, 9 sec; 95% confidence interval [CI], 5 to 13; $P < 0.001$). The median [IQR] VAS rating for ease of intubation was also better in Group R than in Group F (14 [6-42) mm vs 50 mm [17-65], respectively; median difference, 20 mm; 95% CI, 10 to 31; $P < 0.001$). There was no difference between groups regarding the first-attempt success rate, oxygen saturation immediately after intubation, or complications.*

Conclusions *Using the GVL with a deliberately restricted view of the larynx resulted in faster and easier tracheal intubation than with a full view and with no additional complications. Our study suggests that obtaining a full or Cormack-Lehane grade 1 view may not be desirable when using the GVL. This trial was registered at ClinicalTrials.gov: NCT02144207.*

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Résumé

Introduction *Pendant la vidéolaryngoscopie pratiquée avec des lames angulées ou hyper-courbées, il est parfois difficile de réaliser une intubation trachéale en dépit d'une vue d'ensemble du larynx. En cas de vidéolaryngoscopie indirecte, il a été suggéré qu'il pourrait être préférable d'obtenir une vue délibérément restreinte du larynx afin de faciliter le passage de la sonde endotrachéale. Nous avons utilisé un vidéolaryngoscope GlideScope® afin de tester l'hypothèse que l'obtention d'une vue délibérément restreinte entraînerait une intubation trachéale plus rapide et plus aisée qu'une vue globale du larynx.*

Méthode *Nous avons recruté 163 patients de chirurgie non urgente et les avons alloué de façon aléatoire à deux groupes : le groupe F, dans lequel une vue d'ensemble du larynx a été obtenue et gardée pendant l'intubation trachéale avec un GlideScope®, et le groupe R, dans lequel nous avons obtenu une vue restreinte du larynx (< 50 % de l'ouverture glottique visible). Des chercheurs ayant l'habitude de la vidéolaryngoscopie indirecte ont réalisé les intubations. Les intubations ont été enregistrées et les enregistrements vidéo subséquemment étudiés afin de déterminer le temps total nécessaire à l'intubation, la facilité d'intubation à l'aide d'une échelle visuelle analogique (EVA; où 0 = facile et 100 = difficile), le taux de réussite à la première tentative, et la saturation en oxygène après intubation. Les complications ont également été évaluées.*

Résultats *Le temps moyen [écart interquartile (ÉIQ) jusqu'à l'intubation était plus court dans le groupe R que dans le groupe F (27 [22-36] sec vs 36 [27-48] sec, respectivement; différence moyenne, 9 sec; intervalle de confiance [IC] 95 %, 5 à 13; P < 0,001). La note moyenne [ÉIQ] sur l'EVA pour la facilité d'intubation était également meilleure dans le groupe R que dans le groupe F (14 [6-42] mm vs 50 mm [17-65], respectivement, différence médiane, 20 mm, IC 95 %, 10 à 31, P < 0,001). Aucune différence n'a été observée entre les deux groupes quant au taux de réussite à la première tentative, à la saturation en oxygène immédiatement après l'intubation, ou aux complications.*

Conclusion *En obtenant une vue délibérément restreinte du larynx avec un vidéolaryngoscope GlideScope®, on a observé une intubation trachéale plus rapide et plus aisée qu'en obtenant une vue d'ensemble et ce, sans complications supplémentaires. Notre étude suggère que l'obtention d'une vue d'ensemble ou de Cormack-Lehane de grade 1 n'est peut-être pas souhaitable lorsqu'on utilise un vidéolaryngoscope GlideScope®. Cette étude a été enregistrée au ClinicalTrials.gov : NCT02144207.*

Direct laryngoscopy (DL) has traditionally been used to facilitate tracheal intubation in the perioperative setting. More recently, video laryngoscopy (VL) has been recommended as an option for both routine cases and those in which difficult DL is anticipated or has already been encountered.[1-3] Video laryngoscopy with hyper-curved or angulated blades (i.e., indirect VL) can be effective for obtaining a view of the larynx when difficulty occurs or has been anticipated with DL.[4,5] Nevertheless, sometimes this can be at the expense of needing a longer time for tracheal intubation.[4,6,7]

In general, tracheal intubation using DL is facilitated with a full view of the glottis. Although this is often the assumption when using indirect VL, to date this approach has not been clinically validated. The current online operations manual for the GlideScope® video laryngoscope (GVL; Verathon Inc., Bothell, WA, USA) advocates obtaining the "best glottic view" during its use, with an accompanying illustration of a full view of the glottis.[8] Similarly, in a recently published clinical trial regarding the learning curve for GVL-facilitated tracheal intubation, obtaining a grade 1 view was included as one of four indicators of "optimal performance" with the device.[9]

In contrast, other reported series have indicated that passage of the endotracheal tube (ETT) has sometimes been difficult despite obtaining a good view of the larynx during indirect VL.[10,11] Subsequently, a number of publications included the observation that maximizing glottic exposure during GVL video laryngoscopy may, in fact, make tracheal intubation more difficult,[12-15] and they have proceeded to recommend obtaining a more restricted view of the larynx. This viewpoint was echoed later in the GVL instruction manual, where it is acknowledged that "a 1-cm adjustment (withdrawal) of the laryngoscope … may be beneficial to reduce the viewing angle and allow the glottis to drop" and that "maximum laryngeal exposure may not facilitate intubation; reducing the elevation applied to the laryngoscope may make inserting the ETT easier."[8]

This study was undertaken to test the hypothesis that using the GVL with a deliberately restricted view (i.e., Cormack-Lehane grade 2, < 50% of glottic opening visible, with the blade positioned farther away from the larynx) would result in faster and easier tracheal intubation than using a GVL with a full view of the larynx.

Methods

The present study was a single-centre randomized parallel-group superiority clinical trial. It was conducted at the Dalhousie University-affiliated adult tertiary/quaternary care Victoria General Hospital and Halifax Infirmary sites of the Queen Elizabeth II Health Sciences Centre in Halifax, Nova Scotia, Canada from October 2014 to February 2015. The institution's Research Ethics Board gave approval for the trial in August 2014.

Study investigators (Y.G., J.R., A.L., O.H.) screened adult patients presenting for elective surgery. Inclusion criteria were patients with American Society of Anesthesiologists' (ASA) physical status I-III requiring general anesthesia with tracheal intubation. Exclusion criteria included age < 18 yr or > 75 yr, a condition requiring rapid sequence induction of general anesthesia, need for awake tracheal intubation, pregnancy, body mass index > 40 $kg \cdot m^{-2}$, need for a non-standard ETT, known cervical myelopathy, unsecured intracranial aneurysm, and decreased intracranial compliance. Other exclusion criteria included published predictors of difficult GVL use,[10,16] including mouth opening limited to < 3 cm, previous neck surgery or irradiation, or a known previous Cormack-Lehane grade 3 or 4 view during direct laryngoscopy.

After obtaining written informed consent, the following patient characteristics were recorded: age, sex, height, weight, ASA status, modified Mallampati classification[17] (1-4), mouth opening (< 4, 4-6, or > 6 cm), hyomental distance (< 4, 4-6, or > 6 cm), jaw protrusion (i.e., position of lower teeth with respect to upper teeth with mandible maximally protruded: < -5, -5 to +5, > 5 mm), head extension (sternomental distance < 5, 5.0-7.5, > 10 cm), presence of upper teeth (no or yes).

One of the study investigators (Y.G.) used open access software (Random.org; Randomness and Integrity Services Ltd., Dublin, Ireland) to produce a computer-generated block randomization sequence with a block size of 20. Before the start of patient recruitment, two investigators (Y.G., J.R.) prepared a series of sequentially numbered opaque envelopes, each containing a randomization assignment. Patients were randomized on a 1:1 basis to either Group F (a full view of the larynx) or Group R (a restricted view). Full view (Group F) was defined as one in which the GVL was used to obtain a full view of the glottic opening (Fig. 1) with the blade tip positioned near the larynx. The restricted view was defined as a view of < 50% of the actual glottic opening (i.e., percentage of glottic opening [POGO][18] akin to a Cormack-Lehane[19] grade 2 view) with the blade positioned more proximally in the oropharynx, farther away from the larynx (Fig. 2).

Once the participants were in the operating room, the attending anesthesiologist prepared the patients for induction of general anesthesia, including application of standard monitors and placing the patient's head in a neutral position on a standard pillow. A 7.0-mm internal diameter (ID) ETT (Mallinckrodt; Covidien, Mansfield, MA, USA) was prepared for female patients, and an 8.0-mm ID ETT was prepared for male patients and loaded over a lubricated GlideRite® Rigid Stylet (Verathon Inc., Bothell, WA, USA). The intubating study investigator then opened the opaque envelope to reveal the patient's group assignment. Although the patient's group assignment was not announced to others in the room, no formal effort was made to conceal it from either the patient's attending anesthesiologist or the videographer. Denitrogenation was undertaken via a well applied face mask until an end-tidal oxygen reading of at least 80% was obtained. The attending anesthesiologist chose and administered the type and dosages of induction and neuromuscular blocking drugs. A nerve stimulator was placed over the patient's left or right ulnar nerve at the wrist before induction of anesthesia, and after induction, the stimulator was monitored before laryngoscopy began. To reflect real-life intubating conditions, laryngoscopy proceeded when directed by the attending anesthesiologist, sometimes before complete loss of all twitches. A study investigator performed the intubation while an assistant filmed the image displayed on the GVL monitor. All study investigators were experienced with indirect VL, having performed at least 50 intubations with either the GVL or another indirect-type video laryngoscope before the study began. A size-5 GVL reusable blade was used in all patients as this is the only GVL blade in use in our institution and was described in the product manual as acceptable for patients weighing > 40 kg.[8] The blade was advanced and

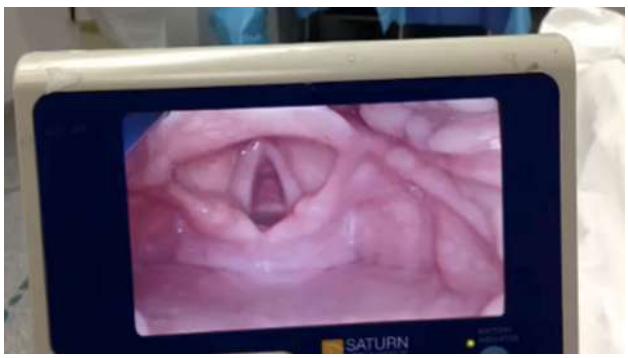

Fig. 1 Full view of the larynx obtained with the GlideScope GVL video laryngoscope (Group F)

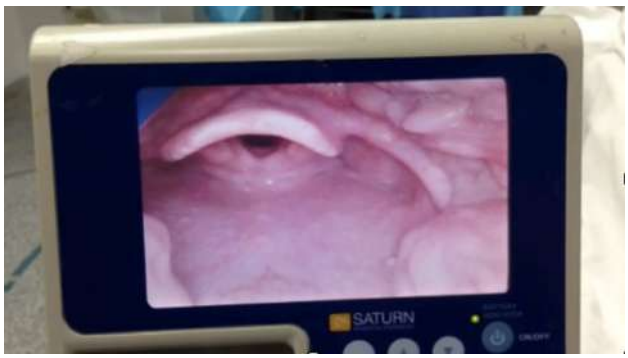

Fig. 2 Deliberately restricted view of the larynx obtained with the GlideScope GVL video laryngoscope (Group R). Only part of the larynx is visualized, and the blade and camera are positioned farther away from the larynx

adjusted sufficiently to obtain the view dictated by the patient's randomization, and at that point, tracheal intubation proceeded while maintaining the specified view.

For Group F, the investigator obtained as full a view of the larynx as possible. The blade with its camera lens was placed close to the larynx and then lifted or gently levered backward in an attempt to visualize the anterior commissure or as much of the larynx as deemed possible without applying excess force to the blade or patient. The study protocol did not necessarily require full glottic exposure, only that a reasonable effort was made to obtain a full view with what, for many, would be a standard technique with the GVL. For Group R, the investigator placed the blade more proximally in the airway such that the blade tip and camera lens were positioned farther away from the larynx. The investigator sought to expose no more than a small amount (e.g., $< 50\%$) of the glottic opening above the corniculate cartilages. No directive was made for either group on whether to lift the epiglottis directly with the blade to help achieve the mandated view.

Once the assigned view was obtained and maintained, the investigator introduced the styleted ETT from the right corner of the patient's mouth. As per the manufacturer's recommendation,[8] the investigator continued advancing the ETT while monitoring its tip with direct intraoral visualization until it progressed beyond the palatoglossal arch. Visualization then reverted to the GVL monitor while freehand ETT delivery proceeded. The study investigator withdrew the GlideRite Rigid Stylet a distance of 5 cm once the styleted ETT advanced through the glottic opening. Intubation was completed by advancing the ETT farther down the trachea to its final position. If there was resistance to forward passage down the trachea, the ETT was rotated clockwise 90° to alleviate impaction of the leading edge of the ETT against the cricoid or a tracheal cartilaginous ring. After successful intubation, the investigator removed the stylet completely, inflated the ETT cuff, attached the anesthesia breathing circuit, and initiated positive pressure ventilation.

Immediately following intubation, the assistant panned the video camera to the patient monitor to record oxygen saturation. Filming was terminated when sustained end-tidal CO_2 ($ETCO_2$) was confirmed. The study investigator checked the patient clinically for any evidence of trauma to the lips, teeth, or oral cavity, measured the ETT cuff pressure, and adjusted the cuff pressure to 22 cm H_2O. At that point, care reverted to the patient's attending anesthesiologist. An anesthesia technician (blinded to the patient's randomization) was paged and, once present in the room, this individual wiped the GVL blade with white tissue and reported any evidence of blood on the tissue or blade. Prior to discharging the patient from the postanesthetic care unit (PACU), the PACU nurse (also blinded to group allocation) completed a form documenting the presence and extent of any hoarseness or sore throat.

A failed intubation attempt was defined in one of three ways: 1) removal of the GVL blade from the patient's oropharynx and re-insertion for a second attempt; 2) a duration of > 120 sec during an intubation attempt; or 3) declaration that the attempt failed or was futile within $<$ 120 sec, with reversion to the opposite view without removing the blade. The initial intubation attempt was deemed to have failed in any one of these three scenarios, and the patient was assigned 120 sec for the attempt. Face mask ventilation was permitted but not required between intubation attempts. After a failed first attempt, the view opposite to that required for the patient's randomization was used for a second attempt. A second attempt was not timed, but the need for two or more attempts was recorded as a secondary outcome. After two failed intubation attempts, the protocol called for airway management to revert to the patient's attending anesthesiologist.

All video recordings of the study intubations were downloaded and separated into individual files. Three video raters then independently assessed the files—G.K. for the primary assessment and analysis of results and subsequently I.M. and K.M. for verification of inter-rater reliability of the data. The primary outcome, total time to intubation (TTI), was defined as the time from blade insertion past the patient's lips to its removal after successful intubation. Pre-specified secondary outcomes were as follows: time from blade insertion to obtaining the assigned view (i.e., no further blade positioning adjustments were evident on the video); subjective rating of the ease of tracheal intubation on a visual analogue scale (VAS); POGO,[18] obtained during the assigned laryngoscopy; oxygen saturation (SpO_2) immediately after removing the blade from the patient; first-attempt success rate; presence of oropharyngeal trauma (as evidenced by blood on the GVL blade or wipe-down tissue or visible upon direct inspection of the patient's lips); and evidence of hoarseness and sore throat immediately prior to discharge from the PACU. The following anchors were used on the VAS for assessing ease of intubation: 0 = very easy (e.g., the ETT was directed to and through the cords and down the trachea easily with no need for redirection); 100 = very difficult (e.g., the ETT required multiple redirections before intubation; it was difficult to attain sufficient vertical or lateral movement of the ETT to gain access to the glottic opening, and/or it was difficult to advance the ETT down the trachea once past the cords).

Sample size consideration

In a preceding pilot series, a full view of the cords was deliberately obtained in 17 patients and held during tracheal intubation, and study results showed a mean (standard deviation [SD]) time of 41.4 (22.2) sec for tracheal intubation. To show a 25% reduction in the total

time to intubation, with standard type 1 and type 2 error rates (alpha = 0.05 and beta = 0.20) in a two-sided test, the calculated sample size was 80 patients per group, 160 patients in total. We increased this number by 10% to 176 patients to allow for dropouts and unanticipated technical difficulties.

Statistical analysis

Data were assessed for normality by skewness, kurtosis, histograms, box plots, P-P plots, and the Shapiro-Wilk test. Because all outcomes failed the Shapiro-Wilk test ($P < 0.001$), all continuous outcome variables were expressed as the median [interquartile range (IQR)] and analyzed using the Mann-Whitney *U* test. The Hodges-Lehmann estimator was used to calculate the 95% confidence interval (CI) for the median difference. Categorical and ordinal outcome variables were analyzed using the Chi square (χ^2) or Fisher's exact test. Cluster-adjusted estimates for statistics were calculated to account for nesting of observations across individual operators.[20,21] Inter-rater reliability for continuous variables was assessed using the intraclass correlation coefficient (ICC) (absolute agreement).

As the intervention differed slightly by sex (e.g., ETTs for males were larger than those for females), we conducted a supplementary analysis controlling for sex when predicting TTI. Total time to intubation was first natural log transformed to account for violations of the normality assumption, and data were then analyzed with 2×2 analysis of variance.

All reported *P* values are two sided. Statistical analysis was performed using SPSS® for Windows, version 22.0 (IBM, Armonk, NY, USA), and R software was used for cluster-adjusted analysis (R Foundation for Statistical Computing, Vienna, Austria).[22]

Results

We assessed 185 patients for inclusion in the study. Overall, 176 patients consented, and 163 were finally randomized. The video capture failed in two of these patients, and in one patient, a CMAC® with a D-blade™ (Karl Storz, El Segundo, CA, USA) was used instead of the GVL. Thus, data from 160 patients were analyzed. Details of subjects' enrolment during the study are summarized in Fig. 3. The baseline demographic and preoperative airway assessment characteristics of the two study groups are summarized in Table 1.

The median [IQR] TTI was faster in patients with restricted exposure (Group R) than in those with full glottic exposure (Group F) (27 [22-36] sec *vs* 36 [27-48] sec, respectively;

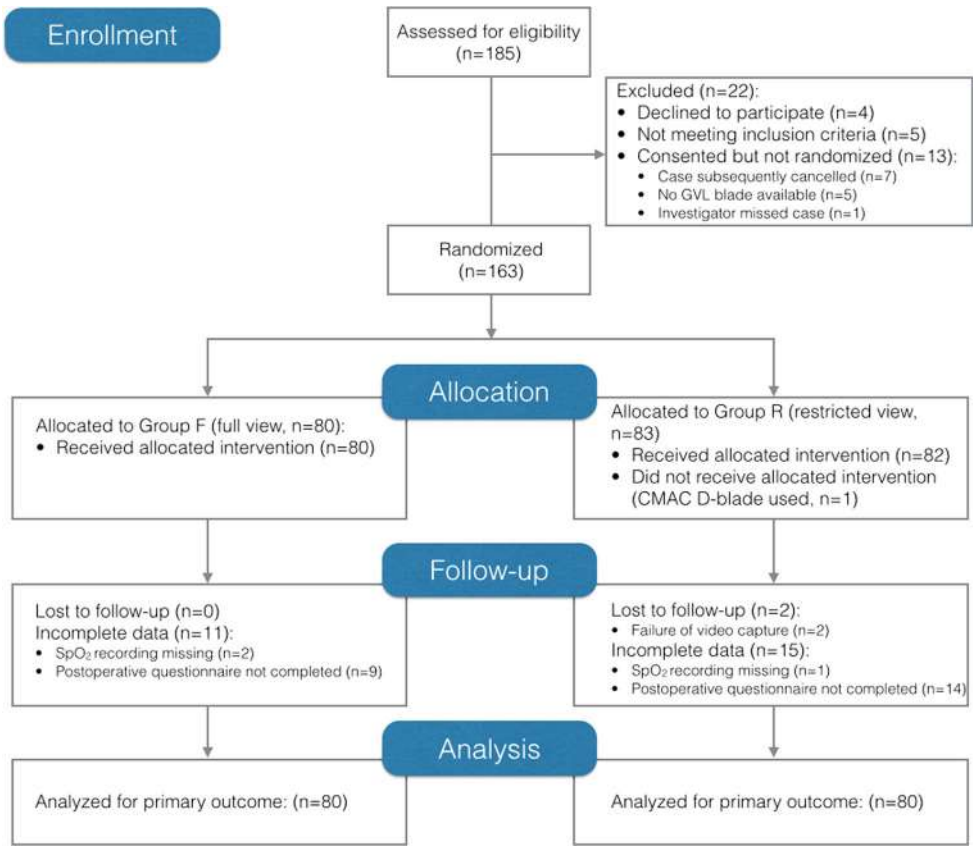

Fig. 3 CONSORT diagram of subject flow through the study

Table 1 Baseline demographic data and preoperative airway assessment parameters

Parameter	Group F (full view) (n = 80)	Group R (restricted view) (n = 80)
Age, yrs	57 [44-65]	57 [48-66]
Male sex (%)	36 (45)	42 (53)
BMI ($kg \cdot m^{-2}$)	28.0 [25.4-32.1]	28.9 [24.9-32.9]
ASA status (I/II/III)	19/55/6	13/59/8
Mallampati Score (1/2/3/4)	33/36/9/2	34/38/7/1
Mouth opening (3-4 cm/4-6 cm/ > 6 cm)	10/36/34	2/46/32
Hyomental distance (< 4 cm/4-6 cm/ > 6 cm)	7/38/35	7/40/33
Jaw protrusion, lower teeth with respect to upper (< −5 mm/−5 to +5 mm/> 5 mm)	0/43/37	1/36/42
Sternomental distance during head extension (5-7.5 cm/7.5-10 cm/> 10 cm)	1/3/76	0/9/70
Maxillary teeth (absent/present)	14/66	23/57
Number of study intubations performed, by investigator (JR/AL/YG/KM/AM/OH)	22/22/19/7/5/5	24/23/16/12/2/3
Number (%) of cases in which epiglottis was directly lifted	55 (69)	2 (3)

Data are expressed as the median [interquartile range (IQR)] or as raw counts/proportions

ASA = American Society of Anesthesiologists; BMI = body mass index

median difference, 9 sec; 95% CI, 5 to 13; $P < 0.001$). There was no significant difference between the two groups regarding the time to obtain the prescribed glottic view (Table 2). The video rater's median [IQR] VAS score assessing ease of intubation indicated significantly easier intubation in Group R than in Group F (14 [6-42) mm *vs* 50 [17-65] mm, respectively; median difference, 20 mm; 95% CI, 10 to 31; $P < 0.001$) (Table 2). All but five tracheal intubations (one in group R, four in group F) were successful on the first attempt, and all were successful within two attempts. Of the five intubations deemed to have failed on the first attempt, two (one in Group F, one in Group R) required two attempts at intubation. In the other three cases (all in Group F), the ETT could be advanced past the cords but could not be advanced down the trachea. Further efforts were judged to be potentially traumatic to the patient before 120 sec had passed. As a result, the GVL blade was re-sited to the Group R view position during the same laryngoscopy session, and intubation was then easily completed.

The POGO was significantly lower in Group R than in Group F (Table 2), validating that the appropriate view had been obtained and maintained. None of the patients' oxygen saturation dropped below 94%. Evidence of trauma was minimal and did not differ significantly between groups. There were no significant differences between the two groups regarding the occurrence or severity of postoperative hoarseness or sore throat (Table 2).

Inter-rater reliability between video raters was good for the primary outcome of TTI (ICC = 0.98) as well as total time to view (ICC = 0.77), POGO (ICC = 0.88), and SpO_2 (ICC = 0.99). The reliability was lower for the VAS score (ICC = 0.64).

Cluster-adjusted estimates confirmed that the significance of the TTI results persisted when analyzed by individual intubating investigators (Table 2). Similarly, the effect of the intervention was consistent across both male and female patients (data not shown).

Discussion

Under our study conditions, we found a significantly faster TTI with the GVL when a deliberately restricted view of the larynx was obtained and maintained during intubation *vs* intubation with a conventional full view of the glottis. The intubation process with this technique was associated with a subjectively easier rating on a VAS, with no difference in complication rates. These results confirm previously published clinician observations and expert recommendations.[12-14]

Various theories have been advanced to explain why a restricted view during indirect VL may facilitate a faster and easier intubation than a full view of the glottis. It may simply be that the more proximal position of the blade and camera lens affords the wider field of view,[13,15] allowing earlier visualization and re-direction of the advancing ETT. Alternatively, it may relate to reduced mismatch in alignment between the ETT tip, which is directed upwardly once it is past the cords, and the trachea, which is oriented in a dorsal direction as it descends into the thorax.[13] This mismatch is often signalled when the anterior wall of the trachea beyond the glottic opening is seen during indirect video laryngoscopy (Fig. 1). No such visualization occurs with the restricted view attained with a more proximally and dorsally angled blade (Fig. 2). Others

Table 2 Study results

Parameter	Group F (full view) n = 80 unless otherwise specified	Group R (restricted view) n = 80 unless otherwise specified	Hodges-Lehmann estimate of median difference [95% confidence intervals]	P value	Cluster-adjusted P value
Time to intubate, sec, median [IQR]	36 [27-48]	27 [22-36]	9 [5 to13]	< 0.001	0.002
Time to obtain view, sec, median [IQR]	10 [7-14]	10 [7-12] (3-23)	0 [-1 to 2]	0.46	0.002[1]
VAS score of ease of intubation, mm, median [IQR] {0=easy, 100=difficult}	50 [17-65]	14 [6-42]	20 [10 to 31]	< 0.001	0.001
1st attempt success, n (%)	76 (95)	79 (99)	—	0.37	0.26
SpO_2 immediately following intubation, %, median [IQR]	n = 78: 99 [98-99]	n = 79: 99 (98-99)	0 [0 to 0]	0.23	N/A[2]
POGO %, median [IQR]	70 [50-90]	10 [10-20]	55 [50 to 60]	< 0.001	0.001
Blood on blade, n (%)	1 (1.3)	0 (0)	—	1.0	0.38
Postoperative sore throat, n (%):	n = 71:	n = 66:	—	0.56	0.39
Mild	57 (80.3)	57 (86.4)			
Moderate	11 (15.5)	8 (12.1)			
Very sore	3 (4.2)	1 (1.5)			
Postoperative hoarseness, n (%):	n = 71:	n = 66:	—	0.43	0.42
None	27 (38.0)	32 (48.5)			
Mild	34 (47.9)	28 (42.4)			
Moderate	10 (14.1)	6 (9.1)			

IQR = interquartile range; POGO = percentage of glottic opening; SpO_2 = oxygen saturation; VAS = visual analogue scale

[1] The median differences and 95% confidence interval for total time to view (TTV) for operators 1-6, respectively, were: −2 [−3 to 0], 4.5 [−1 to 12], 2 [−1 to 4], 0 [−3 to 3], 1 [−13 to 20], 1 [−2 to 4]. Thus, the changed P value for TTV in the cluster-adjusted analyses may be due in part to operator 1 whose results trended in the opposite direction compared with the other operators. Given this pattern, results for TTV are best considered non-significant

[2] Insufficient variability within clusters to calculate; data analysis cannot be performed. This is due to some small clusters combined with low variability in SpO_2 values

have suggested that, with the restricted view, the less ventral angulation of the distal blade and/or the diminished accompanying lifting force results in a more posterior position of the larynx.[14] This positioning provides a straighter path for ETT passage through the oropharynx and larynx and down the trachea -more akin to direct laryngoscopy. Interestingly, a direct lift of the epiglottis was performed in all but two patients in the full view group, whereas the epiglottis was most often not directly lifted in the restricted view group, probably reflecting the more proximally positioned blade (Table 1). In all likelihood, a combination of some or all of the foregoing factors explains the more favourable intubating conditions afforded by the restricted view (Fig. 4).

Our *in vivo* results are consistent with the results of an *in vitro* study by Dupanovic and Jensen published in 2007, in which the authors concluded that a grade 2a view was preferable when using the GVL.[12] Our results may help explain why some GVL-facilitated intubations failed in a number of clinical studies[6] and observational series[10,11] despite a grade 1 view of the larynx. Conversely, in an observational study of factors associated with successful GVL intubations, Siu *et al*. reported a decreasing first-attempt success rate as the Cormack-Lehane grade worsened among their 742 intubations.[23] Nevertheless, their study conditions differed from ours in that the clinicians had varying experience levels in using the GVL. With a different primary outcome (i.e., TTI), the present study was not powered to detect a difference in first-attempt success rates between the full view and restricted view groups.

The study was powered to detect a 25% reduction in TTI. This parameter was used as a surrogate for ease of tracheal intubation as it reflects the potential difficulties that can delay intubation during indirect VL despite a good view. Such difficulties include elevating the ETT tip sufficiently from the posterior pharynx to access the glottic opening, impaction of the ETT laterally with true or false cords or aryepiglottic folds, or difficulty advancing the

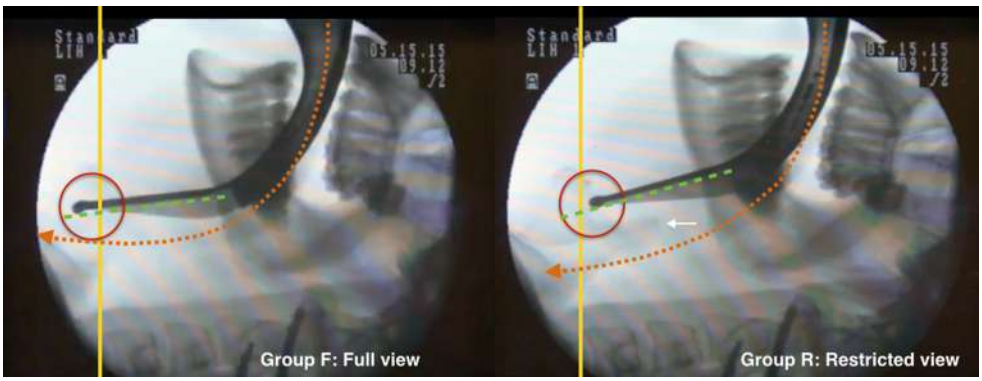

Fig. 4 Two fluoroscopic images obtained for illustrative purposes from the same cadaveric specimen (not part of the study). A vertical (solid) reference line is drawn through the inferior border of C5. When a restricted view (image on the right) is obtained, the GlideScope GVL video laryngoscope blade tip is positioned more cephalad in the airway (circle). The blade is angled more dorsally (dashed line), and the more posteriorly positioned larynx allows a straighter path for passage of the tracheal tube (dotted line). Notice that the epiglottis is not visible in the full view image (left), having been directly lifted by the blade, whereas it is visible in the restricted view image (short arrow, image on the right) with blade placement in the vallecula

ETT down the trachea after passing the cords. Although the true clinical significance of the resulting 9-sec difference between groups could reasonably be questioned, it may still be an indicator of benefit when obtaining and holding the restricted view. The first-attempt success rate is a parameter that is sometimes used as the primary outcome in studies of tracheal intubation techniques.[24] Although intubation may be successful during a single laryngoscopy attempt, the need to re-direct the ETT several times with the accompanying potential to collide with laryngeal structures may result in upper airway morbidity. Thus, TTI may better reflect such difficulties for studies like ours that compare subtleties of laryngoscopy technique.

We analyzed the time to obtain the assigned view (total time to view, or TTV) in order to address the possibility that any detected difference may simply be related to the need for more time to position the blade for one view or the other rather than difficulty manipulating the ETT (Table 2). There was no significant difference in the TTV between groups in the non-cluster-adjusted analysis, so the faster time observed in Group R likely resulted from an advantage in intubating conditions. That said, there was a discrepancy between the cluster-adjusted and non-cluster-adjusted analyses for TTV. The discrepancy probably relates to one operator trending in the opposite direction (i.e., a longer TTV in Group R) from the other operators who tended to have a slightly longer TTV in Group F. The results for TTV are best considered non-significant given the pattern of median differences when assessed by operator and differing results when changes are made to minor aspects of the strategy for analyzing the data. Future research might examine whether features of individual operators (e.g., experience, personal preference) interact with various VL techniques when predicting performance.

We elected to define TTI as blade entry to blade removal rather than the $ETCO_2$ endpoint. For the $ETCO_2$ endpoint, the time from blade removal through cuff inflation, circuit attachment, and reservoir bag compression to appearance of $ETCO_2$ could vary among the staff and yet have no bearing on the ease or difficulty of tracheal intubation itself. In addition, laryngeal visualization is rarely problematic during indirect VL so that confirmation of correct ETT placement through the glottis can almost always occur by visualization on the VL monitor before confirmation of $ETCO_2$. Thus, at least for studies of VL-aided tracheal intubation, we suggest that $ETCO_2$ confirmation is perhaps less relevant as an endpoint than it may historically have been with direct laryngoscopy.

For this study, we elected to use the non-malleable GlideRite Rigid Stylet to facilitate ETT passage. We did this to standardize the shape of the ETT during delivery by multiple study investigators so that any difference detected would be more likely related to the GVL blade position and not the conformation of the styleted ETT. There is some evidence that use of the GVL with the Parker ETT (Parker Medical, Englewood, CO, USA) may result in faster and easier tracheal intubation than with the Mallinckrodt ETT used in this study.[25] Nevertheless, when using the Parker ETT, it is unknown whether blade positioning for a deliberately restricted view would also facilitate tracheal intubation.

Limitations

By necessity, the study investigators who performed all the intubations were made aware of the patient's study randomization just before the procedure. Furthermore, they were aware of the study's objectives and its hypothesis. Both of these factors could have introduced bias. This limitation is

common in many studies of laryngoscopy and tracheal intubation and was impossible to avoid in this study. Similarly, although ostensibly blinded to the patient's study randomization, in most cases, the video rater would have become aware of the assigned randomization while assessing the recordings for the POGO exposed during the laryngoscopy. Our calculations of inter-rater reliability are limited by a potential source of bias: I.M. and K.M. performed their video reviews as a *post hoc* analysis. Nevertheless, all video reviewers were blinded to the others' scores for the individual recordings.

Generalizability

We used the GVL for this study, one of the most widely used indirect video laryngoscopes. It is unknown whether the results of this study are applicable to other GlideScope blade types or other brands of indirect video laryngoscopes. Nevertheless, it might be expected that some of the abovementioned anatomical considerations might also apply to similarly angulated or hyper-curved video laryngoscope blades, e.g., the GlideScope Titanium LOPRO, CMAC® D-blade^{TM}, McGRATH® Series 5, McGRATH® MAC with X blade^{TM} (Aircraft Medical, Edinburgh, UK), or King Vision® (Ambu, Noblesville, IN, USA). Similarly, we do not know if these results would apply to video laryngoscope blades with less curvature or angulation, e.g., CMAC® with Macintosh blade, GlideScope Titanium MAC, McGRATH MAC. To maximize safety for the elective surgical patients recruited to this study, the protocol called for exclusion of those with a body mass index > 40 kg·m^{-2} or published predictors of difficult laryngoscopy using the GVL.[10,16] Thus, it is also unknown whether our findings would apply to these populations.

We elected to have the study investigators perform VL and intubation (rather than the patient's attending anesthesiologist) to maximize the probability that the view mandated by randomization would be obtained and maintained during the process as well as to standardize the level of expertise. Thus, further study is required to determine whether the findings are applicable to a broader undifferentiated population of anesthesia providers with varying levels of experience.

Conclusions

We demonstrated that using GVL indirect video laryngoscopy to obtain a more distant and restricted view of the larynx resulted in a significantly shorter TTI and was associated with easier ETT passage as measured using a VAS. Our study suggests that obtaining a full or Cormack-Lehane grade 1 view may not be desirable when using the GVL. Future studies could help clarify whether these findings would apply to patients with predictors of difficult VL, would be applicable to other indirect video laryngoscopes, would be similar in the hands of less experienced clinicians, or could have a favourable impact on the incidence of airway trauma or other adverse events.

Conflicts of interest None declared.

Author Contributions *Yuqi Gu, Joshua Robert, Kirk MacQuarrie, Orlando Hung, Andrew D. Milne,* and *J. Adam Law* were the study's clinical investigators performing trial tracheal intubations. *Yuqi Gu, Joshua Robert, George Kovacs, Andrew D. Milne,* and *J. Adam Law* performed data analysis and interpretation. *Yuqi Gu, Joshua Robert, Ian R. Morris, Kirk MacQuarrie, Orlando Hung, George Kovacs, Andrew D. Milne,* and *J. Adam Law* critically revised the article. *Ian R. Morris, George Kovacs,* and *Kirk MacQuarrie* were video adjudicators for inter-rater reliability of data. *George Kovacs* and *Andrew D. Milne* were involved in the study design. *Sean Mackinnon* was involved in statistical analysis and interpretation. *J. Adam Law,* corresponding author, conceived and designed the study, submitted the study for ethics approval, and wrote the article.

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